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The cause of occurrence of microorganisms in civil engineering and the dangers associated with their growth

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Abstract

The paper is focused on degradation caused by microorganisms, a process called biodegradation, and on risks for human health caused by them. Bacteria and algae are the primary microorganisms on external building surfaces. These pioneer microorganisms have an enriched space of organic carbon, which is necessary for the growth of any subsequent microorganism which is often mold. Biodegradation is a synergic process of chemical reactions (chemical biodegradation) and physical effects of microbial bodies on building materials (biophysical degradation). The paper is a summary of the current state of art and knowledge in the field of biodegradation.

Keywords: Biodegradation; bacteria; mold; algae; wholesomeness; toxins; Sick Building Syndrome

1. Introduction

Man has been a part of nature and the ecosystem since the beginning of its development. His creations like buildings as well as many other of his products and inventions are surrounded by plants, animals and the wider environment. All these systems influence each other. Also with buildings and organisms these occur in their immediate vicinity or directly on their surface. This problem, in addition to the steadily increasing flood of new information and media reports, involves not only new buildings, but also historical buildings or their remaining parts.

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Microbial metabolites are released into the external environment and these products react with building materials. The new products of those reaction have different water solubility, but mostly there are more water-soluble compounds then before. Physical biodegradation is divided into physical stress (caused by expansion and shrinking of microorganisms´ bodies and cells), abrasion effect, the frost cycle which is connected to retention and drying water through the microorganism. The microorganisms release biotoxins for their own protection but the toxins contribute to a health risk for immune-deficient people e.g. with asthma, allergy, kids etc. A final important point is that microorganisms contribute to Sick Building Syndrome (SBS).

Building materials are damaged by physical and chemical processes in general as has been mentioned. These processes may be the result of weathering, environmental pollution, rising water containing salt dissolved therein, but also through inappropriate building interventions, wrong selection of materials or any of their components, or by bad technological processing. Given that building materials are often heterogeneous systems, it is important to monitor not only damage to the material as a whole, but also damage to its components. Generally the degradation of materials divides into the following groups:

- Physical degradation

Part of the physical degradation going on are such conditions in which the material is subjected to various forces and pressures (inside and outside), which are detrimental to its physical structure. Formation of these forces is often related to variations in temperature, exposure to water and aqueous salt solutions, the formation of new minerals, mechanical vibrations and surface abrasion.

- Chemical degradation

This category includes instances during which the chemical composition of the material is altered, or maybe some of its components, by reaction with the environment (water with pollutants from the atmosphere or from the capillary water, the metabolic products of living organisms, inappropriate conservation work, etc.). The result of the ongoing chemical corrosion is usually a color change or volume change primarily, but also either an increase or decrease in the solubility of the contested folder.

- Biological degradation (biodegradation, biocorrosion)

This term includes degradation processes induced or conditioned by action of living organisms. Their action, however, is essentially manifested as physical degradation (e.g. ingrowth of roots or fungal fibers into a substrate) or chemical corrosion (dissolution of the substrate e.g. "lichen" acids, etc.). This means formation pressures acting on the material or chemical transformation of some of the components [1].

The field of biocorrosion of technical materials originated as a discipline in the fourth decade of the twentieth century, and during the war in Southeast Asia. It was then that there was probably first observed the failure of military technology in environmentally humid tropics, demonstrably caused by microorganisms [2]. Bio-corrosion means any change in the properties of technical materials caused by life activities of organisms, wherein bio-corrosion can act such as microbes, insects, rodents, birds, but also humans [3].

There is a connection of active agents - biodetergents and passive agents – of material in the process of corrosion, which may (but need not) be a substrate for microorganism. With the system of bio-detergents, the material is open and the inanimate material is not able to defend this attack on its own. The interaction of biodeteriogens and material are typical of various forms of bio-deterioration [4].

A simple form of interaction begins already with straightforward settlement of technical products by communities of microorganisms. The practical effects of this interaction are changes to materials: functional (mechanical, electrical, optical, chemical) and morphological (color stains, pulverization, fibrillation). At the start and during the biocorrosion process, there are relevant not only the environmental conditions (macroclimate) but also these conditions are immediately in a contact involving biodeteriogen versus material.

While macroclimate affects the existence of a biodeteriogen in a given environment, microclimate (especially optimal temperature and humidity) may affect which biodeteriogen will attack the materials [5,6].

Nowadays building materials (e.g. sandstone, marble, limestone, igneous and metamorphic rocks but also carbonated concrete) are very good substrates for a variety of microorganisms, which can grow very well in the case of specific conditions. A dozen genera of microbes are identified from construction and these belong to a special group named extremophiles. It is clear that the microbes must live usually at low temperatures (psychrophile) and some often tolerate high pH in constructions, these being named alkaliphile.

Saline efflorescence on walls is not exceptional, and there is a number of specialized bacteria (halophile) on it. Organisms, which can sufficiently live with a low concentration of nutrients and water (found in considerable amounts in building materials) are oligotrophs and osmophiles [7].

Buildings are generally a suitable place for the development of microbes, among wood-destroying insects and rodents. They also provide shelter for birds and arthropods. The most frequently occurring microorganism in buildings are micromycetes (fungi, mold), algae and various forms of insects, particularly mites.

The problem of micromycetes is their production of acids and toxins. Acids are more important in the context of biodegraded building material. Molds produce organic acids such as formic, acetic, propionic, citric, oxalic, and others. This may reduce the pH of building materials, especially in the agricultural and food processing (dairy and meat plants) and in other places where they have a sufficient supply of nutrients and moisture [6] and leaching of calcium.

A further way to identify mold is by detection of the toxins (mycotoxins) which molds produce. The identification of specific mycotoxins is further complicated by the fact that fungi generate so many different metabolites [8]. Methods used to recognise toxins are a non-specific thin layer chromatographic, liquid chromatographic (LC) methods, gas chromatography (GC), mass spectrometry (MS) among others. Examples of identifying toxin are satratoxin H, G, F , iso-F, roridin L-2, several roridin E epimers, hydroxyroridin E, verrucarin J and B etc. (Strachybotris chartarum); alternariols, tentoxin, tenuazonic acids, altertoxin I (Alternaria, black colored in buildings); aflatoxin B1, 3-nitropropionic acid, cyclopiazonic (Aspergillus flavus, the most potent naturally-occuring carcinogen); ochratoxin A, penicillic acid, xanthomegnin, viomellein, vioxanthin (Aspergillus ochraceusus, isolated from building materials), austocystins, versicolorin C, austalides, austamides, austdiols (Aspergillus cf. ustus, isolated from chipboard and gypsum), sterigmatocystin, versicolins (Aspergilus versicolor), chaetomins, chaetoglobosin, sterigmatocystins (Chaetomium globosum), botryodiploidin, secalonic acid D, Roquefortine C, patulin, citrinin, chaetoglobosins, communesins, ochratoxin, tremorgenic verrucosidins, cytotoxic penicillic acid, nephrotoxic glycopeptides (penicillium sp.), trichothecenes trichodermol, trichodermin, harzianum, gliotoxin, viridian (Trichoderma sp.) [9,10,11,12,13,14].

The mycotoxins are related in human disease. The main toxins are as follows.

Ochratoxin A (produced by Aspergillus ochraceus, Aspergillus carbonarius and Penicillium verrucosum) is potentially carcinogenic to humans, and has been shown to be weakly mutagenic, possibly by induction of oxidative DNA damage. That toxin is the most abundant food-contaminating mycotoxin. For rodents consumption of ochratotoxin A causes bifurcation of DNA strands in the kidneys and liver, and hepatic and renal carcinoma. Ochratoxin A has a strong affinity for the brain, especially the cerebellum (Purkinje cells), ventral mesencephalon, and hippocampal structures. The affinity for the hippocampus could be relevant to the pathogenesis of Alzheimer's disease, and subchronic administration to rodents induces hippocampal neurodegeneration. Ochratoxin causes acute depletion of striatal dopamine, which constitutes the basis of Parkinson's disease, but it did not cause cell death in any of the brain regions examined.

Aflatoxin B1 is an aflatoxin (produced by Aspergillus flavus and Aspergillus parasiticus) is a contaminant in a variety of foods including peanuts, cottonseed meal, corn, and other grains and is arguably the most potent known carcinogen. Aflatoxin B1 can permeate through the skin. The most susceptible organ to aflatoxin B1 toxicity is the liver. Aflatoxins can be acutely toxic, carcinogenic, mutagenic and teratogenic. The primary metabolite is also detoxified glucuronoconjugation or sulfuric acid, and is discharged in urine or faeces.

Patulin (produced by Aspergillus sp. and Penicillium sp. and Byssochlamys sp.) is a relatively common contaminant of concentrates and juices. Patulin has broad spectrum antibiotic properties and thus it was validated for possible use in treatment. Experiments on mice, however, revealed that it irritates the digestive tract (causing congestion and bleeding, ulcers), and showed even carcinogenic effects. Patulin is toxic primarily through affinity to sulfhydryl groups (SH), which results in inhibition of enzymes. Oral LD50 in rodent models have ranged between 20 and 100 mg/kg. In poultry, the oral LD50 range was reported as between 50–170 mg/kg. Other routes of exposure are more toxic, yet less likely to occur. Major acute toxicity findings include gastrointestinal problems, neurotoxicity (i.e. convulsions), pulmonary congestion and edema.

Trichothecenes (produced by various species of Fusarium, Myrothecium, Trichoderma, Trichothecium, Cephalosporium, Verticimonosporium, and Stachybotrys.) are powerful inhibitors of protein synthesis. They do this by reacting with components of the ribosomes: the structure within the cell where proteins are made. The specific site of action of T-2 toxin, which is a reaction with a critical site on the ribosomal RNA (rRNA), is known. Protein synthesis is an essential function in all tissues, but tissues where cells are actively and rapidly growing and dividing are very susceptible to the toxins. Compared with some of the other mycotoxins such as aflatoxin, the trichothecenes do not appear to require metabolic activation to exert their biological activity. After direct dermal application or oral ingestion, the Trichothecene mycotoxins can cause rapid irritation to the skin or intestinal mucosa.

The mycotoxins are frequently mentioned in connection with Sick Building Syndrome (SBS). This is a condition when people in a building suffer specific health problems. The objective physiological abnormalities are not generally found and permanent health consequences are rare, but the symptoms of SBS can be uncomfortable for life in this kind of place. Both the patient and the building should be involved in treatment.

In investigating patients with suspected SBS there must be performed a physical examination, so that illnesses not related to those buildings are excluded. The most common health problems occurring in connection with SBS are skin symptoms, mucosal symptoms, respiratory problems, allergy or more general symptoms.

It is very useful to carry out the investigation within problematic buildings because health complications can disappear outside the specific building.

Whenever possible, changes such as ventilation improvements and the reduction of sources of environmental contamination should be initiated, even if specific aetiological agents have not been identified [15]. Several studies in buildings such as schools, office buildings etc. confirm this problem [16,17,18].

1.1. Identification

The issue of biocorrosion of buildings in current practice is narrowed down to two basic questions: the diagnosis and destruction of wood fungi and mold disposal. When it is necessary to protect building against existing organisms it is very useful to know which ones are there and also what is the cause of their occurrence in order to recommend the right and effective solution.

Initially, there are mostly visible areas of microorganisms called biofilm or a typical smell which indicates some problem involving occurrence of undesirable organisms. Then it is time to prepare samples and bring them to laboratory. There are many methods for sampling. One of them and the most useful in our laboratory is smear of the surface by a swab. There is a medium with broth in Petri dish. There is used different kinds of medium depending on the organism to be identified. For example Czapek yeast autolysate (CYA), yeast extract sucrose (YES) and creatine sucrose agar (CREA) are used for the identification of aspergilli and penicillia in combination with examining colony morphology (diameter, color, and surface texture) [19,20].

These samples are cultivated at optimal conditions and then they are identified by metabolic activities and microscopic signs [21,22,23].

1.2. Protection and rehabilitation

There are also possibilities on how to protect buildings and parts of them. The best protection and prevention together is the right building process so as to exclude thermal bridges and repairs where damage can allow water or moisture into the construction (atmospheric, canalization, water for heating, damage of surface finished etc.).

In the situation where organisms occur, it is necessary to choose remedial action. The most useful action is the biocide treatment application. The biocides are divided into four groups by their active substances: alcohols, aldehydes, halogens, quaternary salts. These substances act in different locations of cells and are sometimes used in combination. Some of them disrupt the cell wall, others damage DNA or produce proteins. The recent situation with biocides is quite problematic. The European union have accepted a new law about biocides, and it is on a list of permitted substances.

Many old common substances used are not permitted now or some other one cannot be used in appropriate concentration. For this reason we study modern methods as a biocidal one, for example silver in the form of nanoparticles, ions form- $AgNO_3$), nanofiber textiles (PVA based on an incorporated biocidal compound). The best results are achieved with nanosilver produced according to US patent (it lacks carbohydrate residues) whose effectiveness against mold growth is already evident at a minimum concentration of 28 ppm. The effectiveness of silver and copper ions depends on the final concentration of ions in the nanofiber textiles and on the chosen model organisms. There were also tested nanofiber textiles with the constituents of the biocidal quaternary salts and thiols and their combination. As expected, the anti-mold effective combination was of biocide components.

2. Conclusion

The process of biodegradation is a combination of physical and chemical degradation. When the biodegradation effect is visible the best way to choose the right solution is to know the biodeteriogen. They are identified by microscope and by detection of toxins, which are in some cases very dangerous for human life. The actual situation on the trade of biocides is affected by legislative rules and the list of prohibited biocidal efficient compounds. And it is necessary to invent or discover new methods to fight against mold. One possibility is to take advantage of silver or some other way. It is important to study all toxicity and the movement of agents in the natural cycle including the effects on it.

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